AN ESARDA VIEW OF FUTURE IMPLEMENTATION OF SCIENCE AND MODERN TECHNOLOGY FOR SAFEGUARDS FOLLOWING RECENT ESARDA & INMM INITIATIVES

Sergio Guardini, European Commission, Joint Research Centre, Ispra, Italy
Bruno Autrusson, IPSN, Paris, France
Roland Carchon, SCK•CEN, Mol, Belgium
Göran Dahlin, SKI, Stockholm, Sweden
Domenico Lisi, ENEA, Casaccia, Italy
Herman Nackaerts, Euratom Safeguards Office, Luxembourg
Bernd Richter & Gotthard Stein, Forschungszentrum Jülich, Germany
Matti Tarvainen, STUK, Helsinki, Finland
Maurice D Ward, UKAEA, Risley, UK

Abstract

The new challenges posed by integrated safeguards of ensuring correctness and completeness without cost increase, may require that new techniques are employed or existing techniques modified to cope with the new requirements.

Conscious of this new scenario, the European Safeguards R&D Association (ESARDA) decided to undertake a review of current science and technology initiatives aimed, in particular, at identifying new techniques not yet applied in safeguards that might help in increasing efficiency and effectiveness at no additional cost. With this objective in mind ESARDA organised, together with the Institute of Nuclear Materials Management (INMM), a series of workshops on "Science and Modern Technology for Safeguards" with the aim "to inform the safeguards community about selected sciences and advanced technologies that are currently available or that will become available in the next few years and that could be used to support needed advances in international safeguards" and to "stimulate interchange amongst experts in the various technologies and in safeguards". Three Workshops have been held, the first in Arona in October 1996, then at Albuquerque, September 1998 and the third in Tokyo, November 2000. For the same reason ESARDA also devoted its annual meeting in 1998 in Helsinki, to the topic, "Modern Verification Regimes: Similarities, Synergies and Challenges".

The ESARDA Co-ordinators have examined the outcome of these Workshops to establish whether the aims were achieved, analysing the development status of those techniques and methods presented that may have an application for safeguards and suggesting future directions for the ESARDA activities and for safeguards R&D.

Following the main format followed by the Workshops, the Co-ordinators' analysis has been structured along the following areas:

1. "hard" sciences (instruments, C&S);
2. "soft" sciences (data and information treatment, knowledge building);
3. non-technical (or socio-political) aspects;
4. the rôle of the Regional Systems of Accountancy and Control (RSAC) and of the State Systems of Accountancy and Control (SSAC).

Within these areas, the Co-ordinators have examined whether any techniques have emerged that could be applicable in safeguards and which techniques deserve attention from ESARDA for further analysis in Working Groups or in topical Seminars, Workshops and Symposia.

1. INTRODUCTION

Nuclear safeguards strongly rely (now, and even more in the near future) upon science and technology, in order to ensure effectiveness, transparency and objectivity of conclusions. The new challenges posed by integrated safeguards of ensuring correctness and completeness of States' declaration and drawing conclusions on a State as a whole without cost increase, will be a complex task.

Moreover the changes introduced by the application of the Additional Protocol are leading safeguards further into the area of information treatment and the associated technology. This offers increased challenges that are new for safeguards (embracing, for example, the use of open source information) and therefore needs to be interpreted and adapted, as was required for other disciplines (such as nuclear measurements), when the traditional safeguards measures were introduced. To cope with the conflicting aspects of new requirements/challenges and constraints on the budget will require further R&D, the use of modern science and technology tools and the exploitation of synergies with other disciplines. A combination of all of these factors should help reduce the burden on all parties, improve effectiveness and make better use of the limited resources.

Conscious of these needs in an evolving new safeguards and non-proliferation framework, ESARDA decided to have an overview of science and technology aspects, looking in particular at the possibility of identifying new techniques not yet, or not significantly, applied in safeguards, that could help in increasing efficiency and effectiveness, at the same cost.

To that purpose ESARDA decided to organize, together with the INMM, a series of Workshops on "Science and Modern Technology for Safeguards", whose main aim was "to inform the safeguards community about selected science and advanced technologies that are currently available or that will become available in the next few years and that could be used to support needed advances in international safeguards" and to "stimulate interchange amongst experts in the various technologies and in safeguards". Three Workshops have been held: in Arona (I), (1996) [1], Albuquerque (NM-USA), (1998) [2] and in Tokyo, (2000) [3].

With similar intent, i.e. to identify possible similarities and synergies with technologies employed in other verification conventions and make profit of them to increase safeguards efficiency/effectiveness, ESARDA devoted the 1998 Annual Meeting in Helsinki to a seminar on "Modern Verification Regimes: Similarities, Synergies and Challenges" [4], inviting experts and representatives of other nuclear and non-nuclear verification regimes (CTBT, Chemical and Biological Conventions) to gather together and confront ideas and exchange information with nuclear safeguards specialists.

Some 120 papers were presented in total at the three workshops (together with 67 at the Helsinki seminar), covering a wide range of scientific/technical and non-technical aspects, but almost all dealing with innovative or future applications for nuclear safeguards and other verification regimes.

The ESARDA Co-ordinators decided to perform an analysis of the outcome of the ESARDA/INMM Workshops and of the Helsinki Seminar, in order to establish whether the aims of ESARDA in deciding the workshops were achieved, analysing the status of the development of those more promising techniques and methods presented that may have a potential application for safeguards and suggesting future directions for the ESARDA activities and for safeguards R&D.

Areas of discussions and working groups mandates were not always the same, but for the purpose of the analysis, the Co-ordinators grouped the themes discussed within the workshops into four areas:

Area 1 "hard" sciences (instruments, C&S, Sensors, etc);
Area 2 "soft" sciences (data and information treatment, knowledge building);
Area 3 non-technical (or socio-political) aspects;
Area 4 RSAC/SSAC.

Within these areas, the Co-ordinators examined whether any technique emerged that could be applicable in safeguards, and which techniques deserve attention from ESARDA for further analysis in working groups or in other topical Seminars or Workshops.

As a further outcome of this analysis, the Co-ordinators collected and successively distributed recommendations and suggestions to the ESARDA Working Groups, when needs emerged that could be fulfilled by the technical and scientific ESARDA structure itself.

2. DETAILED ANALYSIS

This section reports, for the four areas, comments and conclusions by the Co-ordinators for individual areas and techniques.

Area 1: Hard Sciences

Environmental Sampling/High Performance Trace Analysis

Certain environmental sample analysis techniques have proven to be powerful safeguards methods to confirm nuclear activities as well as to assist in the detection of undeclared nuclear activities in a facility. Several papers were presented in the different workshops, demonstrating that ES/HPTA is an important technique. The demand for environmental sampling is increasing over the years and its use may not be limited to nuclear safeguards purposes.

The Co-ordinators recommend that more co-ordination between laboratories should be encouraged, which could, among other benefits, result in reducing the current high analytical costs. There is also a need to increase the number of specialized laboratories capable of applying the technique and to carry inter-laboratory round robins on characterised samples. The application of ES/HPTA and the associated analytical techniques still deserve further technical discussions Sessions in Seminars and/or Symposia.

An evaluation of cost/benefit is at this point desirable, distinguishing applications for inside facilities and WAES and taking particular cognisance of any burden on the operator and the State.

Satellite Imagery

As a solution to challenges of verification, commercial satellite imagery (CSI) offers good potential benefits to safeguards for anomaly indications. In addition to being non-intrusive, CSI is increasingly widely available. It has been demonstrated that CSI has applications in several safeguards areas such as confirmation of member States' declarations, detection of undeclared activity, change detection and inspection planning. It could also assist in the identification of areas where environmental sampling should be carried out, and provide baseline information for deep underground repositories. With the availability of additional satellites and improvement in analysis methods and automatic procedures, CSI could become a more efficient and effective tool for safeguards and other verification treaties such as FMCT and CTBT. It is recognised, however, that satellites are not the only source of information but they are one of a number of other open sources of information.

The safeguard community should outline criteria for the interpretation and application of satellite imagery and it should define how to correlate the results given by the technique with other safeguards measures and information.

Unattended Systems/Remote Data Transmission

Unattended systems and remote data transmission will gain more importance in the future safeguards, therefore this is one of the issues that it is worth discussing further in future sessions.

Reliability of local instrumentation and communication lines was discussed. It should be noted that unattended systems and remote data transmission are areas where the information analysis: decision making, artificial intelligence, knowledge generation, data or information validation/authentication will assume outstanding importance and therefore must be considered as well part of the "soft science".

Geo-Physical Techniques
This technology may play a rôle in safeguarding geological repositories. Notwithstanding recent initiatives, primarily the SAGOR project of the IAEA and related activities, there is still a significant body of work to be pursued in this area. It, therefore, has to be followed, even if it does not currently appear to be of first priority for safeguards.

Innovative Fuel Cycles
This topic was discussed in a subgroup, with presentations on areas such as advanced waste management options, advanced reactors and fuel cycle, use of advanced technologies and methodologies developed for proliferation resistant fuel cycles. It was stated that no nuclear system could be made completely proliferation resistant. The aim should rather be to make the civil nuclear fuel cycle the least attractive for proliferation.

Advanced waste management options presented were on partitioning, transmutation and reprocessing as options to reduce the amount of nuclear waste. Concern and focus in the future should be on safeguards aspects for minor actinides (Np, Am, Cm). Np is produced in greater amount when fuel achieves higher burn-up. For the moment there are only minor quantities of separated Np and the IAEA has a program for receiving information on Np. However, with any increase in reprocessing then the possibility for separating Np increases and the need for verification/monitoring may increase.

Another aspect covered was the introduction of thorium in the fuel, which should make the fuel itself less interesting for reprocessing and thereby make the fuel "proliferation resistant". The Korean DUPIC process for direct re-fabrication of spent PWR fuel into CANDU reactor fuel is interesting as the process only handles highly radioactive material, which thereby is difficult to divert.

The group also discussed the safeguards and proliferation aspects for new reactor concepts such as the Russian BREST reactor and the US S-PRISM concept in connection with a compact co-located Spent Fuel Recycle Facility (SFRF). Use of small preloaded, encapsulated transportable reactors was also addressed.

The ESARDA Co-ordinators recognise that this topic is receiving technical and non-technical attention in the nuclear energy community and, therefore, attention must be paid also by the safeguards community.

Area 2: Soft Sciences

Information Treatment
Several papers addressed this issue: it was pointed out that this will be one of the most challenging areas for the future safeguards (and for other regimes also, especially CTBT). Modern technology (such as, computer science, data warehousing, data mining, the Internet) facilitates the collection, transfer and store huge amount of data: but this is not representing a real problem, nor will necessarily present huge costs. What will really be the problem, is the interpretation and the use of the data. Data can be incomplete, wrong or biased. Therefore they need to be filtered, validated, compacted and interpreted in a decision making process.

On the other side, since future safeguards will be more "information oriented" than "measurement oriented", there will be very different kinds of data to be digested: from classical safeguards quantitative data (DA, NDA, weighing) to more general information from open sources that the safeguards world is not used to deal with. This will require new approaches and competences.

Managing diversified data and information will be one of the challenges for the coming years and ESARDA should reflect further on it, with topical seminars, or by establishing an ad hoc working group to deal with the new aspects above mentioned. One of these aspects is represented by the need for establishing new criteria for validating, storing, managing, interpreting "non quantitative" or fuzzy information as well as new decision-making criteria. In classical safeguards, or "statistical nuclear material accountancy", statistical parameters were widely accepted as a basis for safeguards conclusions. Information of different nature need the acquisition of new decision making tools.

One of the possible tools under study and discussed at the workshops is the application of Fuzzy Logic approaches, that have found many applications in other areas, but so far very few in nuclear safeguards. It should be further investigated whether it could help in defining and assessing new criteria for decision making. R&D labs that already apply the technique should report about performances and cost/benefit [5].

Other "diagnosis techniques" [6,7] and knowledge generation techniques [8] should be investigated, always with the intent of managing copious amounts of diversified information and of assessing the probability that a State is complying with the commitment of not hiding undeclared nuclear activities.

Area 3: Non Technical (Socio-Political) Aspects

The Co-ordinators have discussed the methodologies followed and the outcome achieved by the sessions dedicated in the workshops to the socio-political aspects.

The aim of the Sessions was to identify and discuss criteria and related methodologies that in future integrated safeguards scenarios will allow the IAEA to satisfy its mandate of assuring correctness and completeness of States' declarations, without an increase in allocated resources.

The basis to the strategy must remain the non-discriminatory aspects of IAEA verification activities, but the problem arises in defining the criteria. So far the principal criterion has been the amount of SNM in a country or in a plant, but this led the IAEA to spend the majority of its budget in countries where the risk and the perception of the risk is low.

Some of the criteria discussed in the workshops were:

- democracy: but how to define democracy?
- transparency: the implications of using "transparency" as a criterion for defining inspection efforts was explored, but this also implies defining objective and non-discriminatory criteria to define transparency [9]
- making much more use of SSAC is technically a powerful tool to reduce resource needs without loosing effectiveness/efficiency, but again application schemes, and resources allocation criteria have to be developed.

Other important issues treated included the verification of open source information, criteria and related methodologies that in future integrated safeguards scenarios will allow IAEA to satisfy its mandate of assuring correctness and completeness of States' declarations.

It is noted that socio-political aspects will condition future safeguards, therefore it is an area that deserves future efforts and resources. It is recommended that the socio-political aspects should be discussed again in future ESARDA Seminars and Symposia, with the aim of developing approaches to resolve still open questions related to non-technical aspects of future safeguards and non-proliferation regimes.

Area 4: RSAC/SSAC

In the Tokyo Workshop a working group was devoted, for the first time, to: "Regional Systems and State Systems of Accountancy and Control (R/SSAC)". It proved to be a wise and timely decision, since the discussions and presentations raised great interest.

Eight papers were presented, by countries directly interested in the Asian region, by existing RSACs (Euratom and ABACC) and by SSACs. Topics related to the lessons learned from the existing RSACs, as mechanisms for creating confidence building in regional areas. The Asian region is particularly interested in establishing a possible RSAC (see Tokyo Report of Working Group 1 [10]).

The co-operation of S/RSAC with IAEA was also discussed, particularly in view of IS implementation since the cost neutrality condition imposes that ".. the increase of expenses related to the implementation of the new measures should be balanced by the decrease of expenses related to

traditional safeguards". This will lead, on the one hand, to seek for new technologies, but on the other, will require increased use by IAEA of R/SSAC.

ESARDA Co-ordinators, having closely followed the sessions and the discussions in the plenary, conclude that the topic (RSAC/SSAC) must be pursued by ESARDA.

The European Union has a significant experience in RSAC, having the first example of regional system with Euratom. Furthermore, the European Commission has an agreement with the other regional system, ABACC. This experience can fruitfully be made available to countries where it would be essential to establish systems based on confidence building. ESARDA is a forum where scientists, operators, industries, regulatory authorities and non-technical officers, can meet and discuss, even in a non-official way, their technical and non-technical problems. This characteristic of ESARDA has raised a great interest in different world regions and the establishment of similar association may be pursued in the Asian area, with the aim of facilitating with a "step-by-step" approach, the possible creation of a regional system.

ESARDA Co-ordinators consider that it is desirable to discuss RSAC/SSAC related issues further within ESARDA Symposia and "internal" meetings.

3. CONCLUSIONS & FUTURE PERSPECTIVES

Traditional and, to a large extent, strengthened and integrated safeguards, strongly rely upon science and technology, in order to ensure effectiveness of application, transparency and objectivity of conclusions. The new challenges posed by integrated safeguards of ensuring correctness and completeness without cost increase, require that new techniques are employed, and existing techniques are modified, to cope with the new requirements.

ESARDA decided to have an overview of science and technology aspects, looking in particular to the possibility of identifying new techniques not yet applied in safeguards, which could help in increasing efficiency/effectiveness, without cost increase. The Arona, Albuquerque and Tokyo Workshops were very important to set the scenario of the techniques for the future safeguards, within the above framework. The formula of having a broad spectrum of technological areas explored, without substantial limitations and additionally having non-technical aspects (socio-political, RSAC) discussed, has proved to be very fruitful, since several interesting avenues have been identified in both (technical and non-technical) domains.

The last workshop, Tokyo, far from being repetitive, has raised a lot of new interest in non-technical aspects, mainly in the RSAC/SSAC session and for technical issues such as new fuel cycles and remote data transmission and monitoring.

In **Hard Sciences**, classical analytical (DA, NDA) techniques will continue to be the basis of the NMA component of Integrated Safeguards. In sensitive areas, reprocessing, spent fuel assay, waste and spent fuel repositories, further improvements in performances are needed. Developments in these traditional areas are largely reported in regular symposia (of INMM, ESARDA and IAEA).

Continuing R&D and application studies have been highlighted for new areas in strengthened and integrated safeguards: wide-area and site specific HPTA/ES are areas, where R&D is still needed. The Co-ordinators feel that is also now time to evaluate the performances of those techniques (bulk and particle analysis, for inside facility and WAES), with respect to their application in safeguards. Additionally, the Co-ordinators recommend an evaluation of cost benefits and analysis of the successes, in order to assess the frame in which the techniques should be applied for safeguards and non-proliferation. The Co-ordinators point out that, in the cost benefit analysis, the burden on the operator and the State should also be taken into account, since previous experiences show that this aspect may be not at all irrelevant.

The Co-ordinators also recommend that actions are taken to increase cooperation and co-ordination amongst laboratories currently performing HPTA/ES analysis and increase the number of European laboratories capable to perform HPTA/ES.

The use of satellite imagery in safeguards has now been proven and is being implemented. New commercial satellites are now being launched with higher resolution and the price for imagery is reducing, which makes this technique more available for safeguards application, It is now timely for the safeguards community to outline criteria for interpretation and application and to define how to integrate the results of the technique with other safeguards measures and information. As higher resolution imagery becomes available and the technology develops there is still a continuing need for further development of tools and techniques to assist in the analysis of the imagery and maximise/simplify information retrieval.

There will be a greater need for unattended monitoring/remote data transmission in future safeguards. Here also cost/benefit analysis with respect to application is required. In this context the Co-ordinators recommend an assessment of the reliability of sensors, since experience suggests that the weakest element of an unattended system might be the front-end device.

On **Soft Sciences,** the Co-ordinators noted that the volume of data collected for future integrated safeguards will be very large and that the data might often vary greatly in reliability and potential relevance. There is not only the need for collecting, storing and interpreting large heterogeneous data sets from diverse sources, but there is also a need to deal with various kinds of uncertain information, like contradictory, incomplete, fragmentary, vague, biased (purposely or not) or deficient pieces of information. It is necessary to make this information contribute to improve knowledge and to facilitate decision-making.

Open source information is a kind of information that the safeguards technical world has never hitherto dealt with; specialists and special sessions for discussing these completely new aspects may be needed.

Non-Technical (Socio-Political) aspects and **R/SSAC** are dominating the scene for the new safeguards: the Co-ordinators recommend providing opportunity for discussing those aspects in special workshops and sessions in ESARDA Symposia.

ESARDA should make efforts to diffuse to the wide public the issues that are discussed within the Organisation and in the Seminars and Symposia: specialised and general press should always be informed and/or be invited to large open meetings.

The EU together with Argentina-Brazil, have great experience in the application of Regional Systems of safeguards. That is the reason why their contribution was greatly appreciated at the Tokyo workshop. ESARDA could represent a model for a forum of open discussions on technical and non-technical issues, in areas (such as the Asian area) where the need and the importance is felt, to establish safeguards systems based on confidence building. An ESARDA-type association might facilitate a "step-by-step" approach towards the creation of a regional system.

The Co-ordinators recommend that opportunities be identified in the near future to discuss RSAC/SSAC and non-technical (socio-political) issues further within Symposia and "internal" meetings.

Finally, the ESARDA Co-ordinators believe that the series of workshops has provided a very good insight into possible, available scientific techniques. It has also given a very positive contribution to evidence and discuss non-technical aspects and the essential contribution the RSAC give to non-proliferation.

The last of these workshops, in Tokyo, proved to provide an excellent forum for discussing new issues and raised huge interest and discussions within the participants. After Tokyo more targeted workshops/seminars should follow, making use of the outcome of the wide-scope workshops so far

held. Therefore, for the future, thematic events, seminars or special sessions in symposia should be held, with the aim of discussing new technologies and approaches, their adaptation or improvement for (new) safeguards applications. The Co-ordinators recommend that new technologies entering the field of safeguards, should be thoroughly evaluated with respect to their performances in scientific/technical terms, but also analysing the cost/benefit safeguards would have by their application.

One excellent example of the above strategy of focussed workshops is the recent Dresden Seminar [11], which timeously and extensively addressed future Integrated Safeguards: the outcome was judged to be very positive. ESARDA is going to dedicate the next Annual Meeting (Luxembourg, 28-30 May 2002) largely to Integrated Safeguards, with particular attention to the implementation of the Additional Protocol. The title of the planned Workshop is "R&D Responses to the New Safeguards Environment".

Acknowledgements

The collaboration with INMM (and Cecil Sonnier, in particular) in organising the three Workshops and significantly contributing to their success was greatly appreciated.

References

[1] Proc. of the 1st Workshop on "Science and Modern Technology for Safeguards"; Arona, Italy, 28-31 October 1996, Rep. EUR 17264 (1997)

[2] Proc. of the 2nd Workshop on "Science and Modern Technology for Safeguards"; Albuquerque, New Mexico, USA, September 1998

[3] Proc. of the 3rd Workshop on "Science and Modern Technology for Safeguards"; Tokyo, Japan, November 2000 (to be published as EUR Report)

[4] Proc. of the Seminar on "Modern Verification Regimes: Similarities, Synergies and Challenges"; Helsinki, Finland, 12-14 May 1998, Report EUR18681 (1998)

[5] CARCHON, R., RUAN, D., LIU, J., BRUGGEMAN, M., "Application of Logical Computing Methods"; Proc. of the 22nd ESARDA Annual Meeting and Seminar on "Strengthening of Safeguards: Integrating the New and the Old", Dresden, Germany, 9-11 May 2000, Report EUR 19587

[6] HUDSON, P.T.W., "Detection of Hidden Problems and Comprehensive Presentation of Diverse Data in Nuclear Safeguarding", Proc. of 19th ESARDA Symposium, Montpellier, France, Report EUR 1755 EN, 13-15 May 1997

[7] HARRY, J., "Strengthening Safeguards Information Evaluation", 42nd INMM Annual Meeting, Indian Wells, California, USA, 15-19 July 2001

[8] BRABSON, J., "Knowledge Generation", Proc. of the 3rd Workshop on "Science and Modern Technology for Safeguards"; Tokyo, Japan, November 2000 (to be published as EUR Report)

[9] FISHER, W., "Measuring Specific Transparency-a Sensible Concept?", Proc. of the 22nd ESARDA Annual Meeting and Seminar on "Strengthening of Safeguards: Integrating the New and the Old", Dresden, Germany, 9-11 May 2000, Report EUR 19587

[10] NACKAERTS, H., "Report of Working Group 1", Proc. of the 3rd Workshop on "Science and Modern Technology for Safeguards"; Tokyo, Japan, November 2000 (to be published as EUR report)

[11] Proc. of the 22nd ESARDA Annual Meeting and Seminar on "Strengthening of Safeguards: Integrating the New and the Old", Dresden, Germany, 9-11 May 2000